# Transport Systems' Transitional Periods and Long-Term Disruptions: A Systematic Review of the Grey Literature

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**ABSTRACT**

Governments around the world are allocating substantial funding to build, expand, and upgrade transit infrastructure to offer more attractive services that draw higher levels of ridership. These efforts can be hindered by the disruptions in the transit system caused by weather, accidents, structure failures, construction work, or labour disputes. This study uses a systematic review approach to identify and assess the grey literature covering not only transitional periods due to constructions and labour disputes, but also long-term disruptions. The study tries to understand the current state of practice concerning these periods of disruptions and their expected effects on riders, and the array of mitigation strategies used in practice. Few reports were found in the TRID database system discussing disruptions and their mitigation strategies. These reports focused on backup transport systems, policy amendment, disruption assessment, and infrastructure upkeep. The study then investigates the implementation of these strategies in the 26 largest transit agencies in Canada. The results demonstrate that very few transit agencies have clear strategies to mitigate disruptions. Only the Toronto Transit Commission (TTC) has developed a multi-faceted strategy in dealing with disruptions following some of the recommendations from the reviewed reports. This study highlights the disconnect between policy and practice in transit service disruptions research while offering transit practitioners a better understanding of the available mitigation strategies that can help in reducing their negative effect on riders.

**Keywords:** Disruptions, transitional periods, construction, strikes, travel behavior, transit

## INTRODUCTION

Governments around the world are allocating substantial resources to build, upgrade and expand public transport infrastructure, with the goal of offering attractive services that draw higher levels of ridership, thereby achieving several important social, environmental, economic, and well-being goals (*1; 2*). For example, the federal government in Canada revealed a new sizeable, historical level of funding of $14.9 B for new public transit infrastructure in February 202 (*3*). A considerable number of academic studies and professional reports explored the factors affecting user's travel behavior and ridership at the city, route, and stop levels during regular transit service operational periods (*4*). In contrast, the effects of building and/or upgrading transport infrastructures have on travelers' behaviors, needs, and perceptions is a relatively underexplored area in the academic literature. Thus, further research regarding these topics is required to provide professionals and policymakers with the necessary knowledge that would enable them to adequately address or mitigate the inconveniences such projects cause to travelers.

There are several public transport projects that are currently under construction or will be soon, in many Canadian cities including Réseau Express Métropolitain (REM) metro in Montréal, Eglinton Crosstown Light Rail Transit (LRT) line in Toronto, and several bus rapid transit (BRT) lines in Saskatoon, SK and London, ON, making it a suitable case to study. The construction of projects at this scale does not happen overnight, and can take from a few weeks to several months or even years. The impacts of these transitional periods, in general, seem absent from the conversation, and thematically and geographically dispersed. Furthermore, cities do not fully understand what happens during these transitional times: how these transitional periods have long and short-term impacts on transit users, and what strategies and technologies should be utilized to minimize any negative impacts on riders. Similarly, more can be done to account for the negative effects unplanned or unexpected transportation network disruptions have on transport system users. Consequently, the aforementioned gaps or disconnects prompted the undertaking of this investigation.

In this paper, the term "transitional periods" refers to any expected or planned changes in the transport system that alter service structure and quality for an extended period, such as the construction of new transit infrastructure or the substantial upgrade of such infrastructure. At the same time, unplanned or unexpected disruptions of urban rail systems are a major concern for cities worldwide (5). This is due to the fact that unplanned long-term changes or events that significantly affect the transport system, like transit system failures due to temporary shutdowns and closures due to transit operators' strikes and protests, have a pronounced effect on travellers' behavior and perceptions. That is because travel behavior "depends on several factors including individual characteristics, trip flexibility, available transport modes and attitudes towards them, and so on" (*6*). In other words, disruptions to public transport services do not only cause disadvantageous traffic congestions, but could also trigger short-term as well as long-term changes in traveler behavior (*7*).

Albeit different in their origins and characteristics, both transitional periods and long-term disruptions possess several attributes that are common between them, especially in terms of their effects on travel behavior, needs and traveler perception. They both also impact users for an extended period of time. Therefore, both transitional periods and long-term disruptions were included in this review of the grey literature. Operators' strikes and labour disputes causing long-term disruptions were also accounted for in this study. The term "long-term disruption," in this study, refers to interruptions that can go beyond a couple of days. These long-term events can

stimulate the adoption of new travel habits (by changing users' routes or modes of travel) and may even alter users' travel needs.

With this in mind, a systematic review of the grey literature was conducted in order to achieve the following two goals. The first goal is to understand the current state of practice concerning transitional periods and long-term disruptions and their expected effects on travel behavior and users' perceptions. The second goal is to review the applied mitigation strategies and technologies that are used to address or ameliorate any undesirable impacts. This synthesis attempts to bring these two areas of knowledge together in a comprehensive manner. The reviewed grey literature includes professional and governmental documents, non-academic publications and Canadian transit agencies and research centres' documents and reports.

## LITERATURE REVIEW

Only few studies looked at the effects of major infrastructure construction, maintenance or repair projects on travel behavior (*8; 9*). Kattan, de Barros and Saleemi (*9)* investigated the travel behavior changes influenced by the West LRT line's construction in Calgary, Canada, while Zhu et al. (*8)* explored the travel behavioral reactions to service disruptions and capacity reductions caused by metro maintenance projects in Washington, USA. Moreover, studies like Bhutani, Ram and Ravinder (*10)* investigated the impact of metro rail construction work zones on traffic in East Delhi, India.

In terms of unplanned disruptions, Pnevmatikou, Karlaftis and Kepaptsoglou (*11)* combined information on traveler experiences and perceptions during a 5-month-long metro system disruption and attempted to model the mode choice during that period. In contrast, many researchers focused on the consequences of short-term transit system disruptions that last from few minutes to hours (*5*). Saxena, Hossein Rashidi and Auld (*7)* compared how travelers weigh trip attributes differently in the case of either canceled or delayed transit service when choosing a mode of transport. Nguyen-Phuoc et al. (*12)* explored the network-wide impacts of public transport strikes (train, tram, and bus strikes) on traffic congestion in Melbourne, Australia using a network modeling approach as well as a survey that aimed to investigate the mode shift of users when each transit mode's service ceases. Additionally, van Exel and Rietveld (*13)* analyzed rail users' behavioural reactions to a pre-announced national rail strike in the Netherlands based on survey data collected before and after the strike from the same respondents. They indicated that while strikes occur frequently in public transit, studies on their impacts are rare. This agrees with findings of other work in the literature regarding the limited research conducted on the impacts of long-term planned and unplanned transit system disruptions on travel behavior. Furthermore, Spyropoulou (*6)* investigated the effect of different public transport strikes on traffic using loop detector data and studied the strikes' impacts on traffic flow, mean speed, and travel time using Athens, Greece as a reference case. Similarly, Ye, Mokhtarian and Circella (*14)* investigated the effect of an intermittent 9-week closure of a freeway in California, USA, due to its reconstruction, on the travel behavior of commuters. In addition, Danczyk et al. (*15)* discussed the different traffic dynamics that occur in response to long-term unexpected network disruptions as opposed to that of a preplanned closure. MnDOT (*16)* provided a summary of the research available regarding how to mitigate the effects of highway construction projects through the use of transit. It also discussed the strategies that can be used to retain riders after the highway construction project

Zhang et al. (*17)* provided a recent systematic review of the acandmic literature concerning metro system disruption management and substitute bus service. The paper classified

the literature into three groups: preparation for metro network disruption, management of disruption within the metro system, and management of the metro disruption with substitute bus service. Shalaby, Li and Diab (*18)* reviewed short-term rail transit disruption management strategies and modelling approaches. Whilst, Zhu and Levinson (*19)* discussesed theoretical and empirical studies that focus on traffic and behavioral impacts of transport network disruptions. To the best of the authors' knowledge, none of the previous efforts provided an in-depth review of the grey literature related to transitional periods and long-term disruptions to understand the current state of practice.

## METHODOLOGY

A systematic literature review method was adopted in this paper to identify and analyze relevant grey literature regarding the impacts of long-term disruption and transitional periods and the effectiveness of different mitigation strategies. This process involved reviewing leading industry and transport research centres' reports and publications. In addition, a separate search was devoted to reports produced by transit agencies, using Canada as a case study. These reports are important outputs that represent the agencies' policies and approaches used to communicate these vital aspects to the public.

A systematic literature review is a powerful approach that can be implemented to identify and analyze all relevant research on a given topic. The search process carried out to collect the documents for this review can be grouped into two main stages of web-based searches. The first stage involved searching for reports and publications from leading industry and transport research centres. It included executing two subgroups of web-based searches. The first subgroup (Stage 1.1) involved performing 4 different searches on Transport Research International Documentation (TRID) database for topic-relevant reports. TRID is a comprehensive database that includes more than one million records of transport research worldwide (*20*). The four themes of searches were related to disruptions and closures, construction and maintenance, labour disputes, and a general search related to transport system upgrades or improvements. To illustrate an example, the contents of the search bar for the first category were as follows: (Construction OR Maintenance OR Repair*) AND (Transit OR "Public Transport*" OR Ridership OR Satisfaction OR Perception* OR Behavio* OR Bus* OR Demand*). The second group of general searches (Stage 1.2) was also done using Google's search engine. They also were comprised of four main categories. The syntax was as follows: (Upgrad* OR Improv* OR Reduc* OR Clos* OR Disrupt*) AND (Transit OR Bus* OR Transport* OR Rail* OR LRT OR Capacit*) AND (Rid* OR Patron* OR Use* OR Usage OR Using OR Satisfaction OR Perception* OR Behavio* OR Demand* OR Analy*) filetype:pdf after:2011. The search protocol for Google was on a page-by-page basis, such that if no relevant information was found on the first page, then there would be no proceeding to the second page, and so on.

The second stage (Stage 2) was the search for reports and publications by Canadian transit agencies and was performed using the general Google search engine. Three search queries were used similar to the TRID search, specifically, these three categories are disruptions, construction, and labour disputes. These three search queries were performed for each transit agency assessed. As an example, the search syntax used for the first query for Toronto's transit agency was as follows: site:ca "Toronto Transit Commission" AND ("Construction" OR "Maintenance" OR "Repairs") filetype:pdf. The search protocol was the same as the general reports using Google search, whereby relevant information was extracted on a page-by-page basis. If no relevant information was found on a page, then the data extraction would stop at that

page, however if relevant information was found on a page, then proceeding to the next page was mandatory.

As expected, the searches captured a relatively broad range of studies; many which were irrelevant. Duplicates were identified and removed from the final database. For the sake of establishing clear guidelines to elucidate the process of determining which documents are relevant and which are off topic, inclusion and exclusion criteria were formulated and subsequently followed to filter out the out-of-scope documents. Table 1 includes the used inclusion and exclusion criteria. The different stages of the document filtering process carried out in this systematic literature review are outlined in more detail in Figure 1.

**Table 1: Inclusion and Exclusion Criteria for Document Selection Process**

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| • Complete and published documents, reports and studies | • Academic papers, conference posters, books, book chapters, abstracts, dissertations, social media posts, and online videos and presentations |
| • Only documents written in English or French | • Focus on the maintenance or repair of transit vehicles and their improvement |
| • Documents published after 2011 | • Focus on transit trip scheduling, route distribution or operations management during regular disruption-free periods |
| • Documents that discuss the transportation of people, goods and services using land transport modes | • Focus on large cargo or freight transportation, supply chains, maritime and air transport |
| • Documents include sections investigating transport systems' long-term disruption or transitional periods | • Focus on studying travel behavior, ridership and mode choice during regular disruption-free periods only |
| • Documents that include sections discussing impacts of transport systems' closures, failures, or strikes | • Focus on short-term disruptions |
| • Documents focusing on transit ridership or users' travel behaviors, perceptions or needs during long-term disruptions or disruptive transitional periods | • Focus on the impacts of road, street, or lane closures due to processes such as road construction, maintenance or repairs on traffic and travel behavior |
| • Related to transportation, urban studies, social sciences, engineering or environmental studies | • Focuse on safety issues (such as construction zone safety), effects of large-scale natural disasters or that study epidemics or pandemics such as COVID-19 |
| • Documents that focus on the environmental repercussions of transportation systems' disruption or the cessation of public transport modes' operations such as increases in greenhouse gas emissions due to increased traffic or automobile usage | • Documents that mainly discuss transportation disruption modelling such as delay modelling, incident frequency and prediction modelling and financial impact modelling (cost-benefit analysis) |
| | • Documents that are mainly concerned with modelling techniques or the simulation of the transport system whether during disruptions or during regular periods |

Regarding the criteria followed in the document selection process, the inclusion criteria comprised results yielding full documents and reports published after 2011 that include sections focusing on long-term disruptions or transitional periods. Documents that focus on short-term disruptions, the effects of those short-term disruptions, construction technologies, and transit workforce planning and scheduling were excluded. Additionally, only documents written in English or French were included. More details concerning the used criteria can be viewed in Table 1. Subsequent to the selection process, a detailed review of the identified documents and the identification of relevant sections was conducted. Then, data extraction and inputting relevant

information to an excel sheet was performed, which is followed by analyzing the identified information.

A particular focus was placed on the reports produced by the 26 largest transit agencies in Canada regarding long term disruptions, as they outline the current knowledge of transit agencies pertaining to the effects of disruptions and transitional periods on ridership and travel behavior. These reports may also outline the available plans or strategies that are put in place in response to such circumstances, if any. Data regarding these agencies, including the city of each agency, the population served by the said agency, the land area covered and the ridership numbers reported, is illustrated in Table 2.

**Table 2: Cities Included in the Study**

| City | Transit Agency Name | Population (2016) | Land Area in km$^2$ | Ridership (2016)* | Does Agency Provide Multimodal Transport Services? |
|---|---|---|---|---|---|
| Toronto, ON | Toronto Transit Commission-TTC | 2,731,571 | 630 | 538.08 | Yes |
| Vancouver, BC | Translink | 2,439,841 | 2,009 | 232.98 | Yes |
| Montreal, QC | Société de transport de Montréal-STM | 1,942,039 | 499 | 416.18 | Yes |
| Calgary, AB | Calgary Transit | 1,239,220 | 826 | 102.50 | Yes |
| York Region, ON | York Region Transit-YRT | 1,109,909 | 1,762 | 22.41 | No |
| Ottawa, ON | OC-Transpo | 934,243 | 2,790 | 96.47 | Yes |
| Edmonton, AB | Edmonton Transit | 932,546 | 685 | 87.17 | Yes |
| Mississauga, ON | MiWay | 721,599 | 292 | 38.60 | No |
| Winnipeg, MB | Winnipeg Transit | 705,244 | 464 | 48.52 | No |
| Durham, ON | Durham Region Transit-DRT | 645,862 | 2,524 | 10.19 | No |
| Brampton, ON | Brampton Transit | 593,638 | 266 | 23.13 | No |
| Quebec, QC | Réseau de transport de la Capitale-RTC | 577,304 | 569 | 44.91 | No |
| Hamilton, ON | Hamilton Street Railway-HSR | 536,917 | 1,117 | 21.50 | No |
| Waterloo, ON | Grand River Transit-GRT | 468,128 | 314 | 19.69 | Yes |
| Laval, QC | Société de transport de Laval-STL | 422,993 | 247 | 22.01 | No |
| Longueuil, QC | Le Réseau de transport de Longueuil-RTL | 415,347 | 282 | 33.40 | No |
| Halifax, NS | Halifax Transit | 403,162 | 5,492 | 18.99 | No |
| London, ON | London Transit | 383,822 | 420 | 22.57 | No |
| Victoria, BC | BC Transit: Victoria | 347,426 | 376 | 25.50 | No |
| Gatineau, QC | Société de transport de l'Outaouais-STO | 276,245 | 343 | 19.23 | No |
| Windsor, ON | Windsor Transit | 247,368 | 212 | 6.51 | No |
| Saskatoon, SK | Saskatoon Transit | 246,376 | 228 | 12.30 | No |
| Regina, SK | Regina Transit | 215,106 | 180 | 5.21 | No |
| Oakville, ON | Oakville Transit | 193,832 | 139 | 2.85 | No |
| Kelowna, BC | BC Transit: Kelowna | 189,077 | 486 | 4.93 | No |
| St. John's, NL | Metrobus Transit | 131,817 | 462 | 2.97 | No |

* *In terms of annual linked trips in millions*

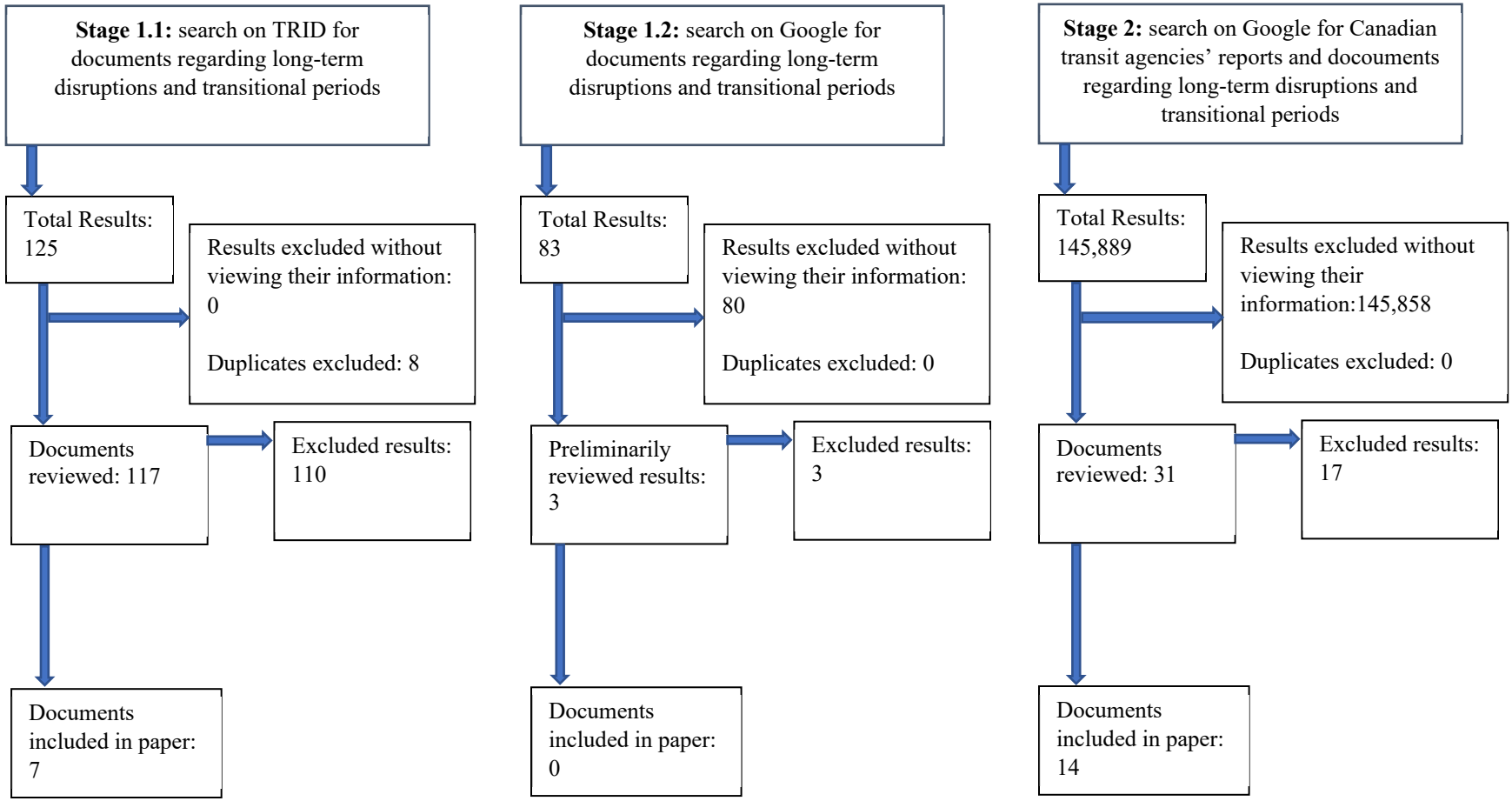


**Figure 1: Document Search and Filtering Process Flowchart**

# RESULTS

## GENERAL REPORTS AND DOCUMENTS

The first stage of this research was to identify and analyze non-academic documents, reports, guides related to long-term disruptions and transitional periods. Table 3 depicts the results of this stage. From an original of 117 documents that were initially identified in Stage 1.1 (see Figure 1), only seven papers were found to have sections with relevant information to this study. Of these seven documents, four predominantly discussed construction-related disruptions, and three explored closures and disruptions from a wider array of sources. No documents were found with relevant information regarding labour disputes, as most of the documents that were available regarding labour disputes were focusing on improving labour agreements and legal issues, rather than their impacts on users and possible ways to mitagte their impacts. All of these documents were sorted based on their search group (i.e. disruption, construction, or disputes) with the exception of Daziano et al. (*21)*, which was found through the fourth generic search. In contrast to Stage 1.1, using a search on Google for Stage 1.2 did not provide any additional results, highlighting the effectiveness of TRID in finding specific transport-related documents.

### Service disruptions

Three documents provided sections discussing long-term disruptions. A dominant theme across these documents is weather conditions and major events, which have the capacity to cause both short-term and long-term disruptions. Marsden et al. (*22)* discussed the use of adaptive capacity for better outcomes after a disruptive event takes place, as physical engineering solutions do not address the societal impacts of disruptions (*22*). They also discussed the importance of using "Smart Resilience Strategies," which is a combination of transport and non-transport actions to minimize the impacts of temporary infrastructure shutdowns, The strategies include using and improving communications with the public and businesses during long-term disruptions.

Yang et al. (*23)* explained that poor infrastructure conditions which lead to lengthy maintenance or unexpected events can cause both long-term and short-term disruptions (*23*). Finally, Daziano et al. (*21)* explored the willingness of locals to pay for improved infrastructure in the wake of long-term weather events that cause severe disruptions in transport services. The study found that people in and around New York City are more willing to pay additional costs for better infrastructure if they were greatly impacted by weather events (*21*). The mitigation strategies across these documents range from improving multi-modality to ensuring transportation infrastructure is adequately maintained.

### Construction

Four documents discussed construction as the core cause of long-term disruptions. The framing of each of these documents varies greatly, however, with some exploring human behaviour as a response to construction, while others are assessments of how construction can be made less disruptive or time-consuming. Cohen et al. (*24)* briefly introduced the London Underground's performance reporting as a strategy to assess disruptions to service, and their economic impacts due to wasted passenger time. Using performance tracking can help in understanding where, how, and when persistent delays occur, improving transit agencies ability in dealing with them (*24*).

CTC & Associates (*25)* compared the mitigation strategies undertaken by various cities in the United States to alleviate the impacts of construction on small businesses (*25*). In some of

these mitigation strategies, alternative routes to businesses were provided for employees and customers alike for the duration of the construction project (*25*). Elkind (*26)* explored how transit construction projects get prolonged, which has implications for the duration of disruptive periods, particularly for construction sites on existing transit corridors (e.g. railway expansion projects) (*26*). Lastly, Hallmark et al. (*27)* demonstrated how human travel behaviour changes in response to deteriorating conditions due to the construction of transport or transit infrastructure (*27*). In particular, travelers engaged in riskier or more dangerous practices with very little improvement in their travel outcomes (*27*). This is a sign of frustration that can be alleviated with changes to lane formatting.

**Section summary**

The non-journal documents mostly discuss how disruptions can be prevented, how users view transit after disruptions, and the cost of disruptions on society and the economy. Only one document provided an explicit discussion of the importance of improving the community adaptive capacity and using smart resilience strategies, which include improving communications with the public. Nevertheless, there is a large gap regarding how labour disputes can cause service disruptions and how they can be mitigated. Overall, there is useful information regarding traveler experience, which can be used by transit agencies to make informed decisions during long-term service disruptions.

**Table 3: General reports and documents**

| Document | Type of Disruption | Issues Addressed | Methods or Approaches | Investigated Factors | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|---|
| (*24*) | Construction | Planning and reporting | Assessing different performance measures of transit agencies across the world and identifying how transferable methods from other agencies can be. | Asset failures. Poor "state of good repair" such as track issues, and station and platform conditions | Performance reporting can help assess where, how, and when persistent delays occur, and how much they are costing the economy via delays (lost working hours, etc.). | State of good repair is an important investment for the long term because delays cost cities and transit agencies potentially billions of dollars annually. |
| (*25*) | Construction | Impact of construction on local businesses | Assessment of various mitigation strategies for construction related disruption from cities across the United States. | Road closures, lane closures, detours etc. due to construction work, impacting regular traffic and access to local businesses | Ensuring the needs of business are being met through consistent consultation, timing construction strategically, and potentially offering fiscal incentives for customers to continue supporting impacted businesses. | Many cities successfully met the needs of local businesses while conducting work on transport infrastructure, often during large scale projects. |
| (*26*) | Construction | Ballooning costs and timelines of transit construction projects | Assessing various delayed and over-budget transit projects in California | Over politicization, lack of transparency, lack of accountability, opposition due to political reasons | Require stricter oversight of construction management. Enact policies to boost transit funding. | Over-politicization can cause over-planning, opposition, cost overruns, and delays. Redundant laws and regulations make transit projects take longer and more costly than necessary. |

| Document | Type of Disruption | Issues Addressed | Methods or Approaches | Investigated Factors | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|---|
| (*27*) | Construction | Dangerous driving behaviour resulting from transit and transport construction-related traffic | Data were collected at freeway work zones for six days to identify behaviors that affected work zone safety and operations, which included forced and late merges, lane straddling, and queue jumping. | forced and late merges, lane straddling, and queue jumping | Use of late merges, longitudinal rumble strips, transverse rumble strips, and left lane merges. It is harder to change human behaviour than it is to change the built environment. | Queue jumping is common in construction zones. This causes aggressive behavior by other drivers, such as lane straddling and physically trying to block queue jumpers. Drivers who engage in lane straddling often slow down the entire queue behind them. |
| (*22*) | Disruption | Resilience to transit disruptions | Reviewing survey samples of snow events, flood events, road closures, and traveler adaptive capacity in the UK | Climate change: weather events accounts for ~12% of delays in the UK's rail transportation network. | Smart Resilience Strategies, a combination of transport and non-transport responses, to minimize the impacts of temporary infrastructure loss. Improve communications with the public and businesses during long-term disruptions. Developing the capacity of travellers and businesses to adapt through greater multi-modality and an increase in smart and flexible working practices. | Societal factors need to be taken into consideration to reduce the overall impacts during and after disruptive events. There is a significant amount of underutilized adaptive capacity in society that should be used to better prepare for such events. |

| Document | Type of Disruption | Issues Addressed | Methods or Approaches | Investigated Factors | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|---|
| (*23*) | Disruption | Disruptions to the Washington metro as a result of aging infrastructure and maintenance work | Assessing ridership before, during, shortly after, and long after infrastructure related disruptions to the Washington metro | Aging infrastructure, maintenance work, poor signalling functionality, track and platform issues | None provided - Goal was to highlight need for improvement | Disruptions due to maintenance and aging infrastructure have both short and long-term impacts on ridership, as constant closing and delaying of services causes lower trust in transport services. |
| (*21*) | Disruption | Weather-related disruptions to NYC's transportation network | A survey designed to collect data on the disruptions that individuals experienced during and after long-term disruptions. 1,552 adults living in the metropolitan area of New York City participated. | Gender, income, employment impact, political leaning, ethnicity | The doceument suggests that the NYC CMA maintain its transportation network as best as possible to avoid major disruptions that can cause the city to come to a grinding halt. | Individuals who missed work are more likely to pay more for improving recovery of the transportation system. A similar effect is observed for individuals who identified themselves as politically liberal. |

## TRANSIT AGENCIES REPORTS AND DOCUMENTS

The second stage of this research included identifying and analyzing transit agencies' reports and documents related to transitional periods and long-term disruptions, and contrasting them to the general reports. Table 4 includes the results of this stage (Stage 2, Figure 1). In total, out of the 26 transit agencies included in the review, only nine transit agencies have relevant information. From these nine agencies, 14 documents were identified to have relevant sections. Half of the documents (7 out of 14) approached the impacts and strategies used during long-term disruptions, while four documents were related to transit service infrastructure constructions, and three documents focused on transit labour disputes. It should be noted that documents in each category were identified according to the keywords and terms that were used in the search. However, some overlap was found among the categories. If an overlap is found, the paper was kept in the most relevant category. For example, two long-term disruption documents identified labour disputes as a major cause for such disruptions. After closely reviewing the purpose of these two documents, these documents were kept in the long-term disruption section.

### Service disruptions

Several documents approached the issue of service disruptions. A number of causes were identified in the documents that can cause longer service disruptions. It should be noted that reports that focused mainly on short-term disruptions were discarded from this grey literature review as indicated by the inclusion and exclusion criteria. Most of the documents did not establish a clear difference between long-term and short-term disruptions; however, if the related discussion indicated longer-term disruptions, the document was kept in the analysis. Common causes for these disruptions included planned closures for service updates or construction, unpredicted events such as flooding, which can result in multiple-day closure. Two documents referred to labour disputes, which include employees' walkouts, as a major cause for long-term disruptions to service delivery.

Most of the documents provided a discussion of mitigation strategies. These strategies included using extra buses and shuttle bus services, rescheduling planned service disruption on lower ridership days such as weekends and holidays, conducting temporary spatial changes to the service structure, rerouting bus services, and integrating fixed-route bus service with on-demand service. One agency indicated the importance of using operational datasets to understand service disruptions to establish a performance management system, rather than taking ad-hoc decisions to manage different types of disruptions (*28*). Only one report provided explicit discussion about the negative impacts of disruptions due to labour disputes on riders' perception and long-term ridership, which would increase the cost burden per hour of service on the agency (*29*).

### Labour dispute

A fewer number of documents focused on transit service workers' disputes and strikes. The city of Ottawa suggested that previous arbitration yielded less efficient transit routing and schedules. It indicated that dispute decisions can have worse outcomes and less practical transit service for the greater public, particularly for socially disadvantaged populations with fewer travel options (*30*). Toronto Transit Commission (TTC) was designated as an essential service under the Toronto Transit Commission Labour Disputes Resolution Act in 2011. The purpose of this act is to prevent dispute-related service interruptions and to ensure the continuity of bus, streetcar, and subway services in the city, unless an established closing time has been designated for upgrades,

repairs, or accident mitigation (*31*). This is to offer the needed mobility, decreasing the significant negative impact of strikes or lockouts on marginalized customers (*32*).

**Construction**

Only four documents focused on construction-related disruptions and delays. One of the documents provided a clear discussion of different types of service interruptions, broken down by their impacts (*33*). According to Kelowna Transit, chronic delays last longer and impact more people, but are generally more predictable than acute delays. Acute delays are those experienced during the morning/evening rush hour, which are shorter in time. Event-related disruptions can cause long-term delays that are more severe. However, they are usually more temporary events.

TTC provided additional resources to deal with construction-related disruptions in terms of offering more services hours to respond to delays and service disruptions related to Eglinton Crosstown LRT construction (*34*). It also provided several backup buses per garage on each weekday to respond to service disruptions and emerging priorities. Similarly, Victoria Transit offered additional services, and backup buses beyond peak capacity for planned and unplanned disruptive events (*35*). In contrast to previous supply-focused approaches, one agency indicates the importance of correctly implementing and using technological development to improve traveler experience during construction (*36*). Using intelligent transportation systems (ITS) can help not only on tracking and dispatching buses but also on managing demand through notifying passengers of service change

**Section summary**

Most of the strategies that were recommended (or used) in the reviewed documents to deal with long-term disruptions and transitional periods were related to using physical measures that are linked to the supply side by offering more services and providing more buses, rerouting transit service, or integrating fixed-route and on-demand services. On the other hand, only very few reports focused on changing managing policies related to designating the transit service as an essential service, as the case of TTC, and the use of technological approaches to managing the demand during transitional periods. Additionally, very few documents provided an explicit discussion of the potential impact of long-term disruptions and transitional periods on demand for transit, and users' perception and satisfaction. In contrast to industry and transport research centres documents (Stage 1), transit agency documents (Stage 2) explained how labour disputes can cause large disruptions to transit agancey ability to offer transportation service.

**Table 4: Canadian transit agencies reports and documents**

| City | Type of Disruption | Cause | Impact | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|
| London (*28*) | Disruption | Unpredicted events (system breakdowns, weather, etc.) | Cancelled or disrupted bus service | Data analysis to establish a base line for each type of disruption to develop appropriate measures. London Transit has an established performance management system with performance objectives for service disruptions. | • It is important to track these occurrences in terms of the time, location and duration of each event, so that a data base can be established for later analysis |
| Saskatoon (*29*) | Disruption | Labour dispute (e.g. employee walkouts) | Disruption or cancellation of bus service | Unspecified | • Labour disruptions can have both short and long-term impacts on service quailty and rider trust in service. The cut in ridership thus makes the cost burden per hour of service much higher on the agency. |
| Toronto (*37*) | Disruption | Planned closures due to signalling updates | Cancelled subway service | Shuttle bus alternatives during closures. Closures occur during weekends and evenings to minimize disruption to commuters. | • Weekend closrues help speed up progress on Automatic Train Control (ATC) updates and track maintenance. 1 full day closure is equal to 5 weeknights of closures. |
| Toronto (*38*) | Disruption | Planned closures due to signalling updates for ATC | Cancelled subway service | Planned closures occur on weekends, evenings, or early Sunday mornings to minimize disruption to passengers. Bus replacements are available. | • Due to generally lower ridership on weekends, full weekend closures for signalling updates and other repairs minimize disruptions to commuters. |
| Winnipeg (*39*) | Disruption | Construction | Closures of bus stops | Bus stops should be moved to temporary alternative locations (detour) when construction impacts the accessibility and safety of service. | • Spatial changes to service structure are needed. |
| York Region (*40*) | Disruption | Unspecified | Closure or disruption of para-transit services | Providing alternative means of transport for disabled persons in the event of a disruption to transit and/or para-transit services. | • Service intrgaration of fixed and on-demand services to meet the need of disabled persons when regular services are made unavailable |

| City | Type of Disruption | Cause | Impact | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|
| York Region (*41*) | Disruption | Labour disputes | Disruption of bus services | Unspecified | • Staffing and labour dispute plans should be prepared in advance. |
| Ottawa (*30*) | Dispute | Labour dispute | Arbitration to settle labour dispute yielded less efficient transit routing and schedules | Unspecified | • Labour dispute resolutions can have worse outcomes for the greater public, including poorer, less practical transit service |
| Toronto (*32*) | Dispute | Labour disputes | Disruption or suspensions of service | The TTC was designated as an essential service under the Toronto Transit Commission Labour Disputes Resolution Act in 2011 to prevent dispute-related service interruptions | • While strikes or lock-outs have the potential to negatively impact all customers, it may have a significant and disproportionate impact on marginalized customers. |
| Toronto (*31*) | Dispute | Labour disputes | Disruption or suspension of service | Designated as an essential service to prevent dispute-related service interruptions | • The purpose is to ensure service of bus, streetcar, and subway lines is continuous as per the provided schedule, unless an established closing time has been designated for upgrades. |
| Kelowna (*33*) | Construction | Construction-related disruptions, and construction accidents, and unpredicted natural disasters | Event-related disruptions | Unspecified | • Chronic delays last longer and impact more people, but are generally more predictable than acute delays. Acute delays are those experienced during the morning/evening rush hour. Event-related delays can be very severe, but are temporary. |
| Toronto (*34*) | Construction | LRT construction | Road closures, delays | 17,500 service hours dedicated to respond to delays and service disruptions are also being added for a total of 89,211 service hours. 6 buses per garage on each weekday | • Additional backup buses and backup hours can be used in instances where services are needed during a disruption |

| City | Type of Disruption | Cause | Impact | Mitigation Strategies | Key Lessons |
|---|---|---|---|---|---|
| | | | | will be available to respond to service disruptions and priorities. | |
| Victoria (*35*) | Construction | Construction and maintenance related disruptions, and driver absenteeism | Delays in bus service | Additional service and backup buses beyond peak capacity are made available for planned and uplanned disruptive events and needed infrastructure maintenance | • Ensuring a pool of additional buses (and drviers) are available will allow for smoother service changes and replacement to deal with unpredicted and predicted service disruptions. |
| Waterloo Region (*36*) | Construction | LRT-related construction disruptions | Road closures, delays, detours for express service | Using intelligent transportation systems (ITS) to help track and dispatch buses, and notify passengers of service changes. | • Technological development can improve traveler experience if implemented correctly during construction. |

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## DISCUSSION

The mitigation strategies for long-term disruptions among the identified documents fall under four broad categories: backup transport services, policy-based measures and amendments, disruption assessments, and infrastructure upkeep and strategic maintenance. These categories are organized in Table 5, which depicts the documents, both from transit agencies and from the non-journal documents, that discussed a mitigation strategy. The documents are also sorted by the disruption they were found with using the keyword search.

Backup transport is the most popular category, with virtually all the cities with a mitigation strategy acknowledging that some form of alternative must be provided during disruptions to regular transit services. The TTC is the most detailed, explicitly stating that 17,500 hours worth of backup bus service is dedicated for disruptions and delays to service (*34*). This additional pool of time is created by reserving 6 buses per garage for use as backup services (*34*). Other transit agencies were far less detailed, stating only that some form of backup transport services will be provided, but no specifications on how many backup vehicles there are, and how many additional service hours are reserved for disruptions. Nevertheless, it was hard from all the documents to understand how transit agencies establish the required additional services and to what extent it provides a comparable service.

The second category is policy amendment. This strategy includes creating smart resilience strategies (*22*), giving more power to transit agencies by amending state laws (*26*), and more controversially, outlawing strikes for transit workers by declaring transit as an essential service (*31; 32*). Policy amendment is the only mitigation strategy that is discussed in detail through documents under each disruption category (disruption, construction, and dispute).

The third category, disruption assessment, was also widely discussed across the eligible documents, but was the main mitigation strategy of Grand River Transit (GRT) and the London Transit Commission (LTC). While these cities lacked the more physical specifications of their mitigation strategies, they commit to providing assessments of disruption events to better prepare for future events of similar nature. Grand River Transit, which serves Waterloo Region in Ontario, also proposes the implementation of Intelligent Transportation Systems (ITS) (*36*). ITS would allow for easier dispatching of backup buses, and can be used to deliver service announcements, and even plan trips and manage fare payments (*36*). However, both documents were prepared by a third-party firm. Thus, whether these measures are actively used or will come to fruition is unknown.

Lastly, infrastructure upkeep and strategic maintenance is a mitigation strategy used by the TTC for planned closures, such as for updates to the subway signalling system (*37; 38*). This mitigation strategy uses a combination of alternative services and strategically timing maintenance work at off-peak periods to ensure the lowest possible disruption is occurring to passengers. Specifically, the TTC intentionally carries out maintenance work on weekends or evenings when most commuters are not using the subway network. This strategy is also loosely suggested by Hallmark et al. (*27)* and Daziano et al. (*21)*, which explain that roadways should be more thoroughly adjusted during construction and that public transit should be maintained better to improve resilience to disruptions respectively (*21; 27*).

Overall, the table shows that TTC is the only agency that reported using a number of mitigation strategies that fall into three different categories of backup transport services, policy-based measures and amendments, and infrastructure upkeep and strategic maintenance while falling behind in disruption assessment mitigation strategies. These three set of strategies were used to mitigate the impact of the investigated aspects of construction, disputes, and long-term

disruptions. The table also shows the extent to which these strategies are dispersed, highlighting the importance of the study.

**Table 5: Documents with mitigation strategies categorized**

| Mitigation theme | Disruption | Construction | Dispute |
|---|---|---|---|
| **backup transport and detouring** | • Toronto Transit Commission (*37*)<br>• City of Winnipeg (*39*)<br>• York Region (*40*) | • Toronto Transit Commission (*34*)<br>• British Columbia Ministry of Finance (*35*) | |
| **policy amendment** | • Marsden et al. (*22*) | • Elkind (*26*) | • Toronto Transit Commission (*32*)<br>• Toronto Transit Commission (*31*) |
| **disruption assessment** | • Dillon Consulting Limited (*28*) | • WSP Global Inc. (*36*)<br>• Cohen et al. (*24*)<br>• CTC & Associates (*25*) | |
| **upkeep of infrastructure and strategic timing of maintenance** | • Toronto Transit Commission (*38*)<br>• Daziano et al. (*21*) | • Hallmark et al. (*27*) | |

## CONCLUSION

This synthesis aimed at understanding the current state of practice concerning transitional periods and long-term disruptions and reviewing the actively used mitigation strategies and technologies to address any undesirable impacts. A systematic review approach of the grey literature was used to identify and assess these mitigation strategies in general industry and research reports, and subsequently reports from Canada's 26 largest transit agencies. This helped in gauging knowledge gaps between professional reports and documents from transit agencies. Synthesising and analyzing what is related to long-term disruptions and transitional periods not only illustrates the state of practice, but also identifies a range of research gaps and potential priority research areas.

The results from this study demonstrate that there is generally a lack of industry and policy reports, documents, and clear contingency plans regarding long-term disruptions in the grey literature. The documents which do contain mitigation strategies can be organized into four categories: backup transport, policy amendment, disruption assessment, and infrastructure upkeep. Even then, while a few documents focused on economic impacts and assessment of

disruption causes, user perceptions and behviour during these events are minimally addressed or analyzed. More importantly, very few documents provide a comprehensive plan regarding what transit agencies should do to maintain adequate services during a long-term disruption.

Following the assessment of documents producted by Canadian transit agencies, it was found that most of the recommendations from the grey literature were absent from transit agencies' contingency plans. This has major implications, as transit agencies are facing more frequent long-term disruptions with the emerging effects of climate change. Only one transit agency, the TTC, makes consistent and high-level explanations of why disruptions occur, how they are mitigated, and what future disruptions could look like. This could be due to a number of reasons, the primary ones being that Toronto is the largest city in Canada with the most active transit agency, thus having the most financial and human resources to procudce robust contingency plans, and that the TTC is prone to long-term closures due to ongoing signalling updates. Together, both the need and capacity to develop contingency plans for long-term disruptions give Toronto the strongest overall policy on disruption planning. Among the remaining transit agencies, the majority of the documents only make mention of instances of past disruptions, or low-level prevention or mitigation plans in case of a disruptive event, with a limited focus on understanding long-term disruptions and mitigation strategies effects on users. Finally, this study highlights the disconnect between policy and practice in transit service disruptions research, while offering transit practitioners a better understanding of the available mitigation strategies that can help in reducing their negative effect on riders.

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## AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Diab & El-Geneidy; data collection: Mohammed, Noureldin; analysis and interpretation of results: Mohammed, Noureldin & Diab; draft manuscript preparation: Mohammed, Noureldin & Diab. All authors reviewed the results and approved the final version of the manuscript.

## REFERENCES

[1] CUTA. TRANSIT VISION 2040.In, 2015.

[2] OECD/ITF. ITF Transport Outlook 2017.In, 2017.

[3] canada, G. o. *Largest public transit investment in GTA history will create jobs and kickstart the economy*. https://www.canada.ca/en/office-infrastructure/news/2021/05/largest-public-transit-investment-in-gta-history-will-create-jobs-and-kickstart-the-economy.html. Accessed July 20, 2021.

[4] Miller, E., A. Shalaby, E. Diab, and D. Kasraian. Canadian transit ridership trends study: Final report.In, University of Toronto Transportation Research Institute, 2018. p. 140.

[5] Currie, G., and C. Muir. Understanding Passenger Perceptions and Behaviors During Unplanned Rail Disruptions. *Transportation Research Procedia,* Vol. 25, 2017, pp. 4392-4402.

[6] Spyropoulou, I. Impact of public transport strikes on the road network: The case of Athens. *Transportation Research Part A: Policy and Practice,* Vol. 132, 2020, pp. 651-665.

[7] Saxena, N., T. Hossein Rashidi, and J. Auld. Studying the tastes effecting mode choice behavior of travelers under transit service disruptions. *Travel Behaviour and Society,* Vol. 17, 2019, pp. 86-95.
[8] Zhu, S., H. Masud, C. Xiong, Z. Yang, Y. Pan, and L. Zhang. Travel Behavior Reactions to Transit Service Disruptions: Study of Metro SafeTrack Projects in Washington, D.C. *Transportation Research Record,* Vol. 2649, No. 1, 2017, pp. 79-88.
[9] Kattan, L., A. de Barros, and H. Saleemi. Travel behavior changes and responses to advanced traveler information in prolonged and large-scale network disruptions: A case study of west LRT line construction in the city of Calgary. *Transportation Research Part F: Traffic Psychology and Behaviour,* Vol. 21, 2013, pp. 90-102.
[10] Bhutani, R., S. Ram, and K. Ravinder. Impact of Metro Rail Construction Work Zone on Traffic Environment. *Transportation Research Procedia,* Vol. 17, 2016, pp. 586-595.
[11] Pnevmatikou, A. M., M. G. Karlaftis, and K. Kepaptsoglou. Metro service disruptions: how do people choose to travel? *Transportation,* Vol. 42, No. 6, 2015, pp. 933-949.
[12] Nguyen-Phuoc, D., G. Currie, C. De Gruyter, and W. Young. Exploring the impact of public transport strikes on travel behavior and traffic congestion. *International Journal of Sustainable Transportation,* Vol. 12, No. 8, 2018, pp. 613-623.
[13] van Exel, N. J. A., and P. Rietveld. When strike comes to town…anticipated and actual behavioural reactions to a one-day, pre-announced, complete rail strike in the Netherlands. *Transportation Research Part A: Policy and Practice,* Vol. 43, No. 5, 2009, pp. 526-535.
[14] Ye, L., P. Mokhtarian, and G. Circella. Commuter impacts and behavior changes during a temporary freeway closure: the 'Fix I-5' project in Sacramento, California. *Transportation Planning and Technology,* Vol. 35, No. 3, 2012, pp. 341-371.
[15] Danczyk, A., X. Di, H. X. Liu, and D. M. Levinson. Unexpected versus expected network disruption: Effects on travel behavior. *Transport Policy,* Vol. 57, 2017, pp. 68-78.
[16] MnDOT. Mitigating Highway Construction Impacts with Transit.In, Minnesota Department of Transportation, 2012.
[17] Zhang, S., H. K. Lo, K. F. Ng, and G. Chen. Metro system disruption management and substitute bus service: a systematic review and future directions. *Transport Reviews,* Vol. 41, No. 2, 2021, pp. 230-251.
[18] Shalaby, A., L. Li, and E. Diab. Chapter 14: Rail transit disruption management: a comprehensive review of strategies and approaches.In *Handbook of Public Transport Research (HOPTR)* Edward Elgar Publishing, Cheltenham, United Kingdom, 2021. pp. 280-313.
[19] Zhu, S., and D. M. Levinson. Disruptions to Transportation Networks: A Review.In *Network Reliability in Practice*, Springer New York, New York, NY, 2012. pp. 5-20.
[20] TRID. *Home - Transport Research International Documentation - TRID.* Transportation Research Board. https://trid.trb.org/. Accessed July 20, 2021.
[21] Daziano, R., U. Cornell, C. University Transportation Research, Research, and A. Innovative Technology. Analyzing the Willingness to Improve the Resiliency of New York City's Transportation System.In, 2015. p. 67p.
[22] Marsden, G., J. Anable, J. Shires, I. Docherty, C.-o. Organisation for Economic, and Development. Travel behaviour response to major transport system disruptions: implications for smarter resilience planning.In, 2016. p. 27p.
[23] Yang, Z., H. Masud, G. Liu, S. Zhu, U. George Mason, C. Transportation Informatics University Transportation, R. Office of the Assistant Secretary for, and Technology. Behavior

Reactions to Transit Network Disruptions: A Case Study on Washington Metro SafeTrack Project.In, 2018. p. 29p.
[24] Cohen, H., J. Barr, L. L. C. Spy Pond Partners, Kko, and L. L. C. Associates. State of Good Repair: Prioritizing the Rehabilitation and Replacement of Existing Capital Assets and Evaluating the Implications for Transit.In, Transportation Research Board, 2012. p. 132p.
[25] CTC & Associates. Mitigating Construction Impacts on Local Businesses.In, Minnesota Department of Transportation, 2019. p. 39p.
[26] Elkind, E. Back in the Fast Lane: How to Speed Public Transit Planning & Construction in California.In, UCLA School of Law, 2014. p. 12p.
[27] Hallmark, S., A. Mudgal, T. Stout, B. Wang, A. Iowa State University, T. Iowa Department of, C. Midwest Transportation, Research, and A. Innovative Technology. Behavior Study of Merge Practices for Drivers at Work Zone Closures.In, 2011. p. 64p.
[28] Dillon Consulting Limited. *London Transit Commission route structure and service guideline review*, 2015.
[29] PwC. *Review of Saskatoon Transit resources and scheduling*, 2017.
[30] City of Ottawa. *Follow-up to the 2011 audit of the OC Transpo scheduling process for bus operators*, 2015.
[31] Toronto Transit Commission. *TTC as an essential service*, 2016.
[32] ---. *Staff report: essential service review*, 2017.
[33] City of Kelowna. *Kelowna transportation master plan existing and future conditions technical report*, 2019.
[34] Toronto Transit Commission. *2020 TTC and Wheel-Trans operating budgets*, 2019.
[35] British Columbia Ministry of Finance. *Review of BC Transit*, 2015.
[36] WSP Global Inc. *Grand River Transit business plan 2017 - 2021*, 2018.
[37] Toronto Transit Commission. *Explanation of subway closures*, 2014.
[38] ---. *Subway closures - 2019 review and 2020-2022 forecast*, 2019.
[39] City of Winnipeg. *Manual of temporary traffic control on city streets*, 2020.
[40] York Region. *York Region 2020 to 2023 multi-year accessibility plan*, 2020.
[41] ---. *York Region Transit (YRT/VIVA) transit operation and maintenance contracts*, 2014.